Autonomous Profilers for Carbon System and Biological Observations

Casey Moore
Western Environmental Technology Laboratories (WET Labs), Inc.
PO Box 518, Philomath, OR 97370-0518
Phone: (541) 929-5650 ext. 11 fax: (541) 929-5277 email: casey@wetlabs.com

This grant is part of a National Ocean Partnership Program (NOPP) with

James K.B. Bishop
EO Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS90-1116
Berkeley, CA 94720-0001

Russ E. Davis
Scripps Institution of Oceanography
La Jolla, CA 92093-0230

Contract Number: N00014-99-C-0449

LONG-TERM GOALS

Our long-term goal is to understand the biogeochemical dynamics of the ocean's upper kilometer. Such an understanding is fundamental to prediction of the processes partitioning carbon between atmosphere and ocean and to the redistribution of carbon and associated elements within the water column. Key to predictability is understanding day-to-day variability of processes governing abundances of carbon species (dissolved and particulate, inorganic and organic) in the water column.

OBJECTIVES

Our objective is to demonstrate the concept of low-cost autonomous profiling vehicles outfitted with a suite of low-power optical, physical and chemical sensors. When widely deployed, these will permit high-frequency four-dimensional observations of the variability of ocean biological processes, carbon biomass, upper ocean physics, and parameters of the carbon system in the upper 1000 m. It is envisioned that once proven, such vehicles can be widely deployed to explore carbon variability on global scales. An immediate objective is to demonstrate that we can explore Particulate Organic Carbon (POC) and Particulate Inorganic Carbon (PIC) biomass variability in the water column on daily to seasonal time-scales in remote and extreme environments.

APPROACH

Platform. The autonomous platform to be used is the Sounding Oceanographic Lagrangian Observer (SOLO; Davis et al., 2000), a low-cost autonomous profiling float. This well-proven ocean physics platform, augmented with new optical sensors for biogeochemistry, will permit the rapid and precise determination of two important products of photosynthesis, Particulate Organic Carbon (POC) and Particulate Inorganic Carbon (PIC), as well as physical data (T, S and derived density stratification)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **Autonomous Profilers for Carbon System and Biological Observations**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Western Environmental Technology Laboratories (WET Labs), Inc.,,PO Box 518,,Philomath,OR,97370**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

relevant to understanding the variability of these products. SOLO will be modified to accommodate POC and PIC sensors and with ORBCOMM transceivers for bi-directional telemetry of data at much higher data rates than the previously used System Argos.

Implementation of the faster telemetry permits transmission of data from the expanded sensor suite while significantly reducing the time (and hence susceptibility to biofouling) of the float in the surface layer. Scripps Institution of Oceanography (SIO) leads the modification of SOLO. Coordination and testing of the integrated float/sensor package is a joint effort led by EO Lawrence Berkeley National Laboratory (LBNL) and SIO. LBNL is responsible for calibration and data reduction.

POC sensor. Bishop (1999) and Bishop et al. (1999) demonstrated that beam attenuation at 660 nm is strongly correlated to POC in open ocean waters. Accurate and precise long-term high-frequency measurement of POC in the upper 1000 m requires the following: (1) a stable and precise, and (2) effective antifouling protection for transmissometer optics. Work on these issues is led by Western Environmental Technology Laboratories, Inc. (WET Labs, Inc.).

PIC sensor. Particulate inorganic carbon occurs mostly as the mineral calcite and in most locations calcite is the dominant mineral in suspension. For this reason, we investigated optical properties (e.g. refractive index, birefringence...) specific to calcite that might be used to quantify PIC suspensions. LBNL is developing and proving the PIC sensor concept and WET Labs, Inc. is implementing the PIC sensor concept in hardware and addressing biofouling issues.

WORK COMPLETED

POC Sensor. Efforts on the POC sensor have concurrently focused upon achieving required electro-optical performance and in providing a mechanical package suitable for deployment on the SOLO platform. We initially modified an existing C-Star commercial transmissometer with a new electro-optical package to achieve performance levels required for this project. This includes short-term stability approaching 0.0001 m^{-1} and overall stability with temperature and time to approximately 0.001 m^{-1}. The two critical issues involved in achieving this stability included achieving stability with temperature ranging from 0-30 degrees C. and retarding biofouling.

Figure 1 shows meter output versus temperature and short-term precision with the modified electro-optics package. As can be seen, stability with the modified electronics meets required performance levels.. These levels represent performance an order of magnitude above presently commercially available transmissometers.

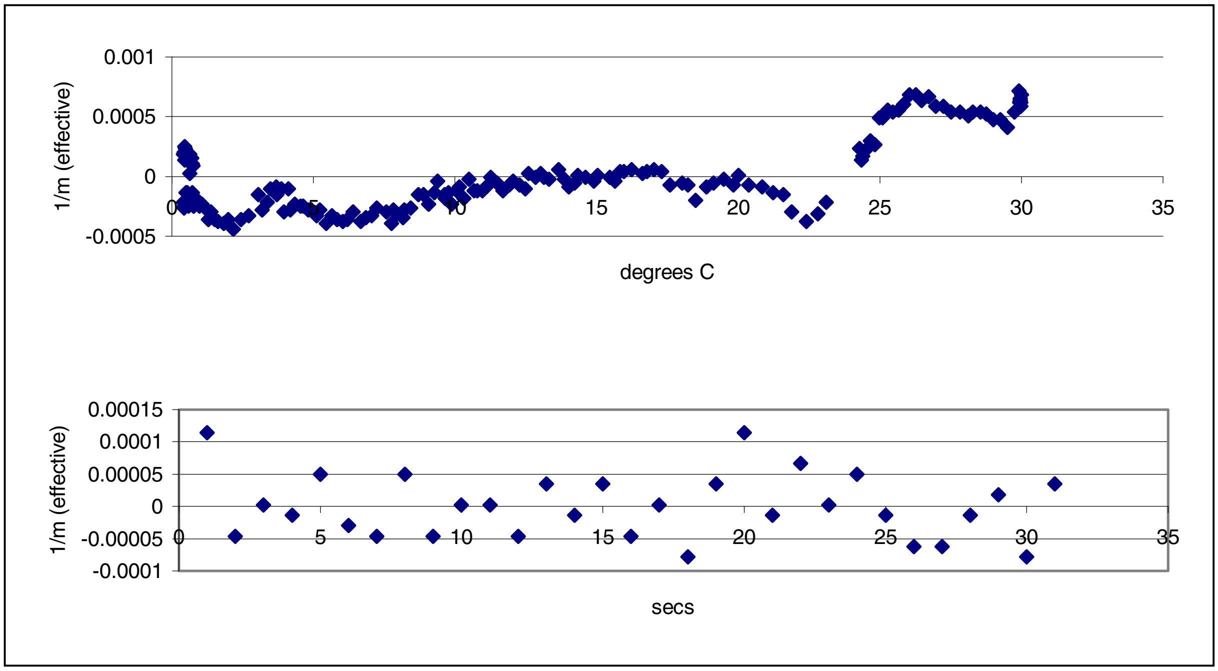

Figure 1 – Effective attenuation coefficients (in air) as a function of temperature and time demonstrating instrument stability and precision.

While the modified C-Star provided performance levels required for the POC detection, the packaging of the instrument proved ill suited for easy incorporation on the SOLO float. The instrument's negative buoyancy and the inherent difficulty of incorporating active biofouling remediation were its two biggest drawbacks. As a result we are now developing a package that incorporates transmitter and receiver housings separated by a unistrut frame that mounts on both face flanges. (See Figure 2.) This package will initially house the modified C-Star electro-optics circuitry but will eventually contain electronics under development in other related contracts.

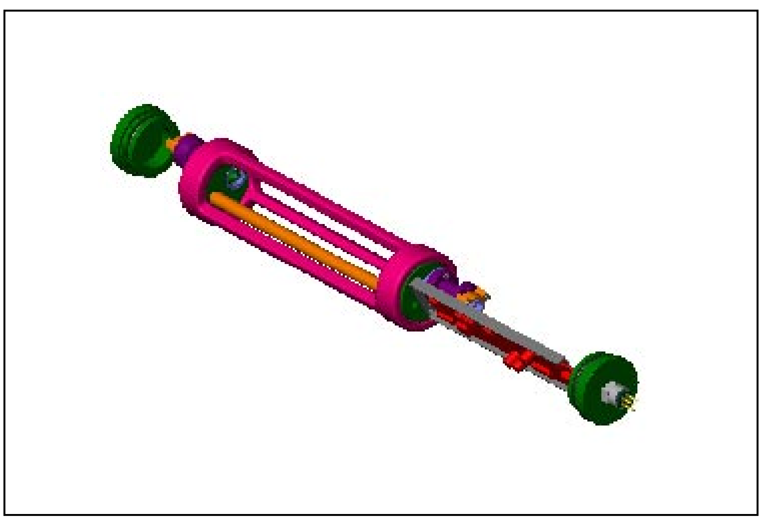

Figure 2 – Cutaway view of new POC sensor.

In order to provide nutural buoyancy the initial design using the unistrut frame will actually be slightly longer than the present 25 cm path C-Star, however the package height will eventually get reduced

with the introduction of the next generation of electronics. The 2.5-inch diameter is scaled to provide non-contact optical shutters at both the receiver and the transmitter. These shutters were initially developed and tested under the aegis of other NOPP related funding. Once the initial fall tests are completed, incorporation and testing of the shutters will proceed.

PIC sensor. After initial tests of the PIC sensor concept by Bishop and Guay, Dr. Guay visited WET Labs and, using a C-Star frame, we worked together to validate the transmissometer based approach for a field based instrument. We next built a prototype PIC sensor by bonding polarizing plates to the optical windows of a transmissometer. This meter is presently at LBNL undergoing further tests. Concurrent with these tests we are incorporating a package design similar to the POC sensor with internal polarizer adjustments for field deployment in our upcoming field experment.

RESULTS

We are still in the instrument development stage and do not yet have any scientific results.

IMPACT/APPLICATIONS

The sensors and methodology employed in this project can easily migrate to other autonomous platforms; furthermore, the work of this partnership will lay the foundation for expanded sensor suites and their integration onto recoverable autonomous self-navigating platforms designed to quantify both the reactants and products of photosynthesis, and the rates of carbon-system processes.

TRANSITIONS

None as yet.

RELATED PROJECTS

1 - Jim Bishop (LBNL) and Russ Davis (SIO) are supported separately by ONR under this National Ocean Partnership Program project.

2 - WET Labs is working in partnership with Percy Donaghay and Margaret Dekshineks of the University of Rhode Island and Alfred Hanson of SubChem Systems, Inc. in developing novel chemical and biological sensors for an autonomous profiler system.

3 - WET Labs is working in partnership with Mary Jane Perry of the University of Maine and Charles Erickson of the Applied Physics Laboratory at the University of Washington in developing new biological and chemical sensors for the APL virtual glider mooring.

REFERENCES

Bishop J.K.B., 1999. Transmissometer measurement of POC. Deep-Sea Res. I. 46(2), 355-371.

Bishop, J.K.B., S.E. Calvert, and M. Y.-S. Soon, 1999. Spatial and Temporal Variability of POC in the Northeast Subarctic Pacific. Deep-Sea Research II . 46(11-12) 2699-2733.

Davis, R.E., J.T. Sherman and J. Dufour, 2000. Profiling ALACEs and other advances in autonomous subsurface floats. *J. Atm. Oceanic Tech.*, accepted.